RCA

LB-826

A TRISTIMULUS PHOTOMETER

RADIO CORPORATION OF AMERICA

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Approved

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Introduction

Several efforts have been made in the past to use photocells for direct color measurements. Fast spectrophotometers were designed and one instrument displayed the spectral response for all practical purposes instantaneously.[1] These instruments facilitated the accumulation of the basic data considerably; however, they left considerable computational work to be done in order to establish the visual effect of the measured color.

In order to avoid the tedious job of product integration to obtain the ICI coordinates, it was proposed to construct an instrument with certain photocell-filter combinations approximating the ICI standard distribution factors.[2] However, the extent of approximation is limited particularly for the $\bar{x}$ curve with its double components.

This bulletin describes the new instrument which provides a good approximation of the ICI coordinates by means of a novel unidirectional crossfeed arrangement, which injects a portion of the $\bar{z}$ response into the $\bar{x}$ response circuit. Three integrated signals can be read on three meters simultaneously and the ICI coordinates can be computed by one addition and two division operations.

General Discussion

Since 1931 the physicist has been enabled to define colors in a coordinated manner. While the coordinates or the whole system may be subject to some criticism, nevertheless, the ICI tristimulus specification is accepted as the best basis to compare colors at present. Before the adoption of the ICI standards the visual comparison was found to be more complete than spectrophotometric data, since as it is well known that two lights having different spectral distributions may look alike. While this fact may not concern the color tester of a filter or ink, etc. it is basic concern in color reproducing processes using primary components such as color photography, color television, etc. For these processes the spectrophotometric data are emminently suitable if applied by means of the tristimulus specification since the color may be designated by two coordinates from the spectrophotometric data according to the relations:

$$X = \int R\,\bar{x}\,d\lambda \quad (1)$$

$$Y = \int R\,\bar{y}\,d\lambda \quad (2)$$

$$Z = \int R\,\bar{z}\,d\lambda \quad (3)$$

$$x = \frac{X}{X + Y + Z} \quad (4)$$

$$y = \frac{Y}{X + Y + Z} \quad (5)$$

[1]Sziklai and Schroeder: "Electronic Spectroscopy", *Journal Applied Physics*, p. 763, October 1946.

[2]Twyman and Perry. British Pat. 324,351.

Where R is the spectral response of the sample (light and/or subject), $\bar{x}$, $\bar{y}$ and $\bar{z}$ are the three distribution factors of the standard ICI observer, Fig. 1, and x and y are the desired coordinates.

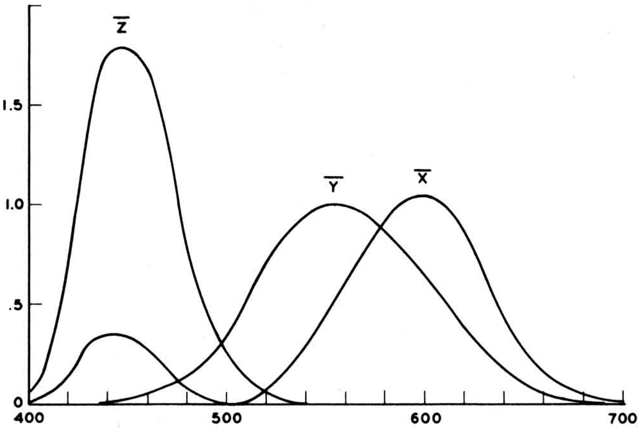

Fig. I – Tristimulus specification of the I.C.I.

The product integration shown in Eqs. (1), (2) and (3) is usually done numerically and it presents a tedious and long job if it performed with a large number of the coordinates. If the number of these coordinates is reduced the precision of the color specification is reduced as well. It is customary to specify spectrophotometric data in the 400-700 millimicron region with an ordinate given at least at every 10 millimicrons, thus requiring at least 30 sets of data.

Tristimulus Photometry

In order to avoid the tedious job of product integration indicated by Eqs. (1) to (3) a proposal was made by Twyman and Perry[2] to construct an instrument having three photocell-filter combinations with responses corresponding to the spectral distribution factors referred to above. Several such instruments were developed, the most successful being one developed by R.S. Hunter[3]. However, the extent of approximation of the desired response was limited particularly for the $\bar{x}$ curve with its double component, and thus the accuracy of these instruments was seriously limited. It was shown that this discrepancy is most serious when two samples of assimilar spectral distribution are compared. Further, the proper characteristics are even harder to obtain when the sample is not a reflector and therefore, spectral illuminants cannot be used. Both of these objections apply to color television images.

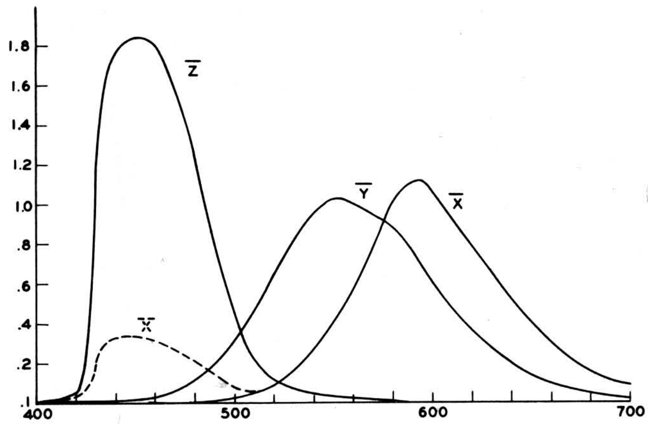

Fig. 2 – Spectral response of the photomultiplier tristimulus meter.

Fig. 2 shows the spectral responses of three selected IP22 multiplier phototubes and Corning C5-3-113, CS-4-111 and C5-5-79 filters respectively. Upon comparing Fig. 1 and Fig. 2, the lobe of $\bar{x}$ in the region of 4000-5000 A units is conspicuous by its absence in Fig. 2. However, the similarity between the shapes of $\bar{z}$ and this lobe makes it possible to use an attenuated $\bar{z}$ signal as a substitute for the minor lobe of $\bar{x}$. This may be accomplished in a number of ways, however, one particular solution seems to be most suitable when the general design of the tristimulus photometer is considered.

The circuit diagram of the tristimulus photometer is shown in Fig. 3. The power supply was designed to keep the actual device compact and light. An r-f supply is used for the high voltage required by the multipliers. It was considered simpler to use a rectifier and a resistance divider to supply the voltages rather than to use taps on the coil, particularly since the capacitance of three multiplier phototubes was considered excessive. Th r-f oscillator is operated from a well-filtered power supply in order to provide a constant sensitivity on short time basis. This is particularly important when the instrument is used for color television images, since any 60-cycle ripple would provide different sensitivity fo different areas of the scanned picture.

[3] "A Multi-Purpose Photoelectric Reflectometer", *Journal of Research National Bureau of Standards*, Vol. 25, p. 581, 1940.

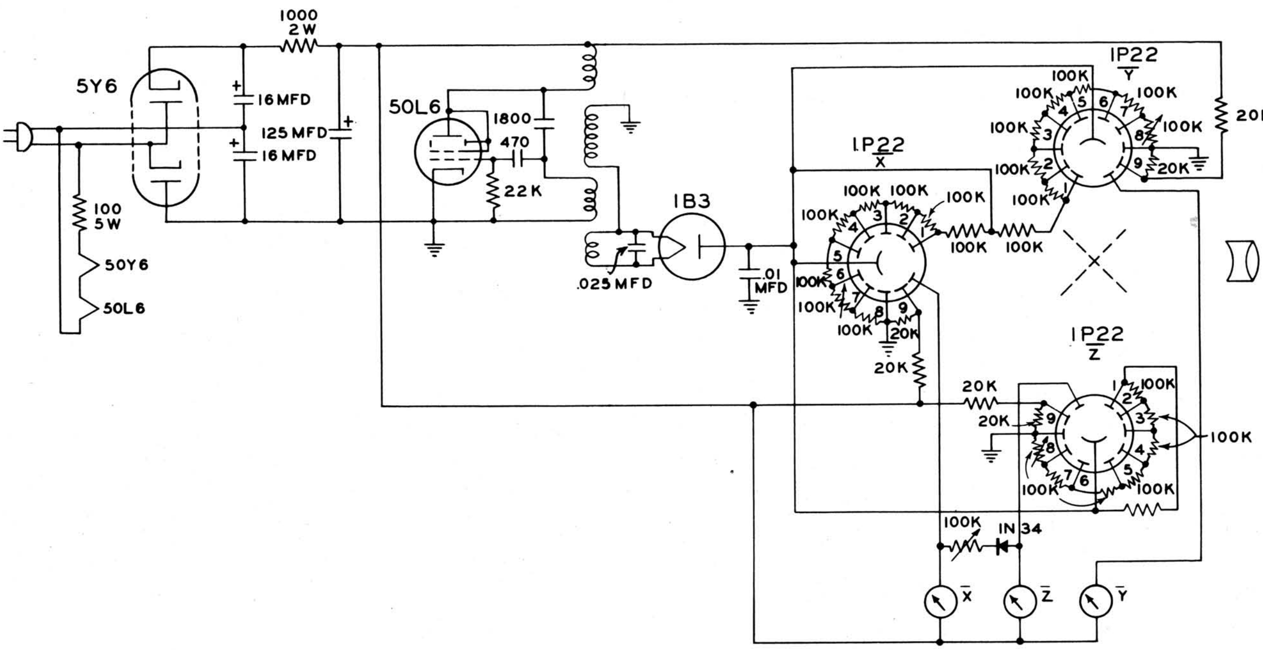

Fig. 3 – Circuit diagram of tristimulus photometer.

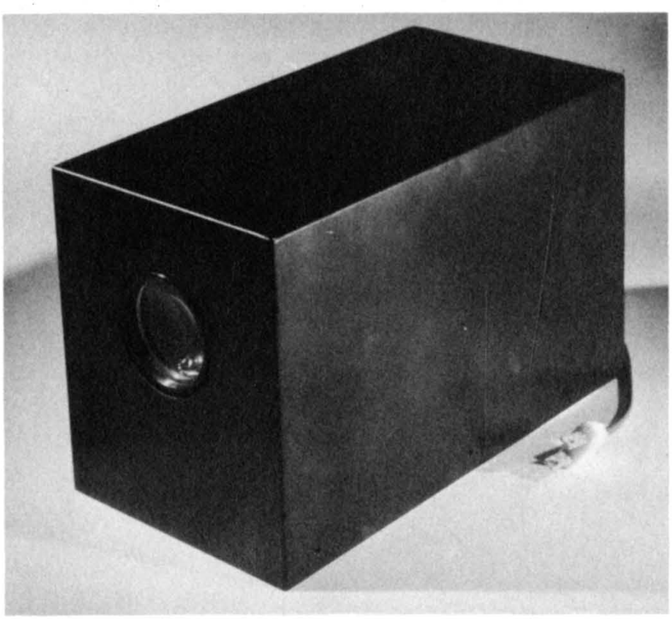

Fig. 4 – Photograph of tristimulus photometer.

The light is fed through a crossed semi-transparent mirror to the three multiplier phototubes. Due to the low sensitivity of the S8 surface and the inefficiency of the CS-3-113 amber filter, the reading of the $\bar{x}$ channel is an order lower than the reading from the other channels (in practice a 1-microampere meter is used for the $\bar{x}$ channel against the 10-microampere meters in the other channels.) *The novel principle of the instrument is shown by the*

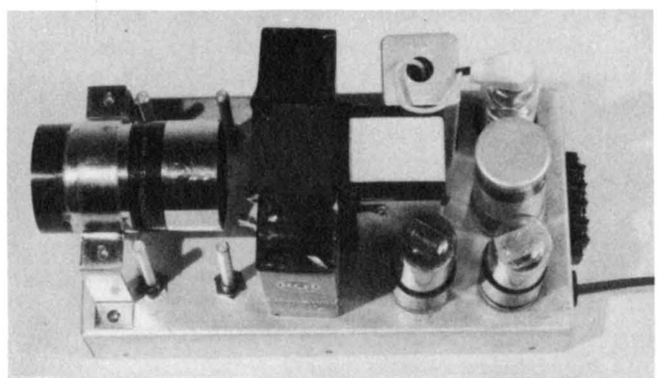

Fig. 5 – Tristimulus photometer, cover removed, showing optical arrangement of the instrument.

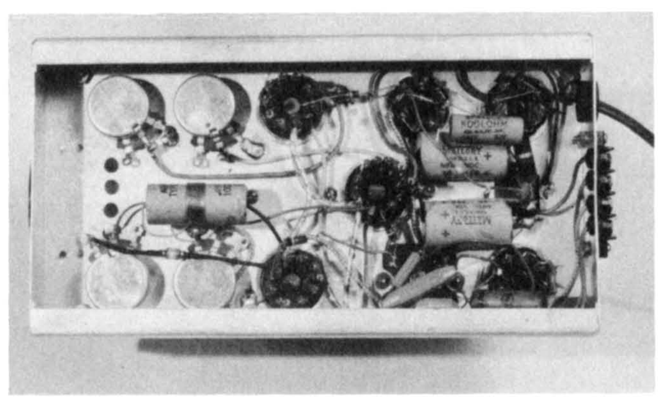

Fig. 6 – Bottom view of tristimulus photometer chassis.

cross-feeding circuit from the $\bar{z}$ circuit into the $\bar{x}$ circuit. In order to feed the $\bar{z}$ current into the $\bar{x}$ meter but prevent the flow of cur–

rent in the opposite direction a rectifier is provided. This simple means of unidirectional crossfeed is successful due to the fact that the sensitivities of the two channels are different by a proper magnitude and order.

Fig. 4 shows the complete instrument which is 5 x 6 x 10 inches. Fig. 5 shows the instrument with its cover removed. A 5-inch lens focuses the light on the three multiplier phototubes through a beam splitter consisting of two crossed semi-transparent mirrors. Three potentiometers adjust the relative gain of the three phototuoes and a fourtn one adjusts the amount of crossfeed. The remaining three tubes are the low-voltage rectifier, the high-frequency oscillator and rectifier. Fig. 6 shows the wiring which indicates the simplicity of the instrument.

Fig. 7 shows the results obtained with the instrument. The circles indicate the colors of the colors as obtained by spectrophotometric analysis, and the crosses the measurements obtained by the instrument. The results from the spectral colors were computed from Fig. 2. The squares indicate the data that would be obtained if the crossfeed and therefore the minor lobe of $\bar{x}$ were omitted.

One particular application of the device may be the use of two instruments, connected to three zero-center meters. One of the instruments then can be aimed at the original subject,

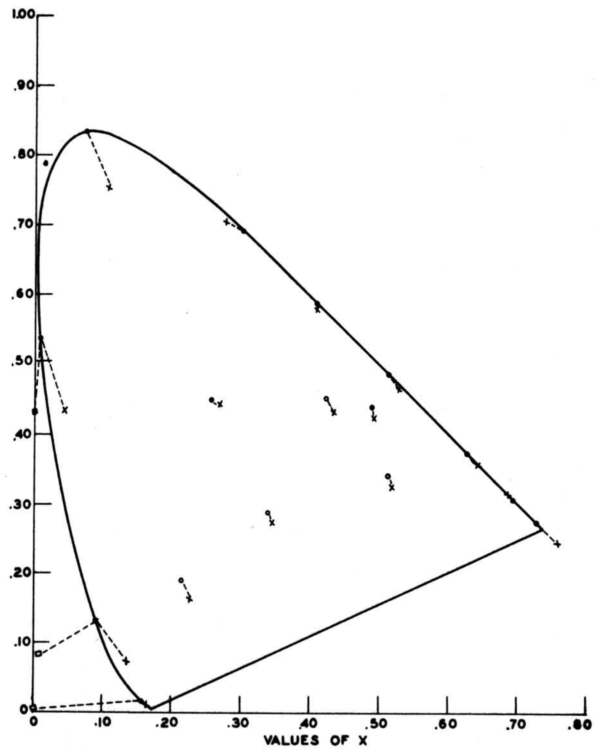

Fig. 7 – Chromaticity diagram showing accuracy of the instrument.

the other at a reproducing device. A zero indication on the three meters then would correspond to a perfect match for the standard observer, while positive or negative indications would provide sense and magnitude of the required corrections.

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